International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 3 Volume No.5 May – 2021 DOI: 10.46647/ijetms.2021.v05i03.001
ISSN: 2581-4621

Taguchi Method for Multi-Objective Optimization of Cutting Parameters in Turning Operations AA7129 Alloy Reinforced with B_4C & TiC

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Abstract. This paper will discuss parametric optimization of the turning process using the Taguchi method in order to improve the quality of manufactured goods, as well as engineering design development for studying variation Turning of Al7129 metal matrix reinforced with Titanium carbide (TiC) and Boron carbide (B4C) powder. Metal Matrix Composite with Carbide tool for carrying out experiment to optimize material removal rate and surface roughness.
There are three machining parameters i.e., spindle speed, feed rate and depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so that optimised value of each parameter can be obtained. In this project dry turning of Al7129 as a work piece and carbide insert tool. The range of cutting parameters are cutting speed (180, 350 and 500 m/min), feed rate (25, 80 and 125 mm/rev), depth of cut (0.2, 0.6 and 1 mm). Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab version 16. Taguchi method stresses the importance of studying the response variation using the signal to noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrolled parameters. It is predicted that Taguchi method is a good method for optimization of various machining parameters as it reduces number of experiments. A confirmatory test confirms the results, which indicate the optimum values of the input factors.

Keywords—**Optimization, Depth of Cut, Feed rate, Spindle Speed, Taguchi Orthogonal Array**

1. INTRODUCTION

Turning is a major machining process that includes metal cutting as well as the removal of metal chips to produce a finished product with the desired shape, size, and surface roughness. Engineers must overcome obstacles in order to obtain optimal parameters for desired output using available sources.

Taguchi's method describes how to reduce variation in order to improve quality through offline or online quality control. Offline quality control helps to improve process quality, whereas online quality control helps to maintain conformance to the original or intended design. The primary goal of Taguchi's design is to ensure that the product performs well even in adverse conditions.

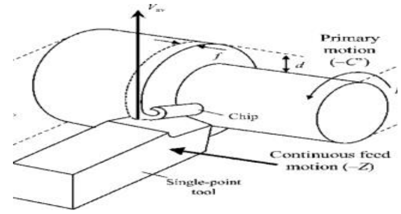
It contributes to the product's durability. The Taguchi method is used in a very short period of time and with minimal effort. As a result, Taguchi's method is being used in a variety of industries to improve process quality in the manufacturing sector.

Surface roughness and cutting force are both critical parameters in the machining process. Cutting force is required for power machining calculations. Cutting forces have an impact on dimensional accuracy, work-piece deformation, and chip formation.

In industries, components with a specific surface roughness are always required based on the needs of the customer. This can be accomplished through the optimization process.

1.1. Single Point Cutting Tool

Single point cutting tools have one principal cutting edge which is mainly used for cutting. These tools are used for turning, boring, planning etc. used in machines like lathe, boring and shaping machines. Single point cutting tools contain following parts: - shank (this is the main body of the tool), flank (which is adjacent below the cutting edge), face (the surface upon which chip slides), nose radius (it is the point where cutting edge intersects with side cutting edge.



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Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal can be defined as the machining of an external surface.

2. OBJECTIVE OF WORK

The aim of this work is to observe cutting parameters in turning and calculate the optimum value of the parameters to optimise surface roughness and tool wear using the Taguchi method. The statistical analysis will be carried out in order to improve machining operations, which will be used for quality control of machining parts

2.1 MATERIALS & METHODOLOGY

Turning of Aluminium 7129 (Al7129) has been used as matrix phase and Titanium carbide (TiC) and Boran carbide (B4C) powder as reinforcement phase. The chemical composition of the base metal and its physical properties are shown in Tables 1 & 2 respectively While the chemical compositions and physical properties reinforcement are shown in Tables 3 & 4 respectively.

Element	**Content (%)**
Aluminum, Al	90.9 – 94
Zinc, Zn	4.2 - 5.2
Magnesium, Mg	1.3 – 2

Tables 1: Aluminium 7129 (Al7129) chemical composition

Element	**Weight Percentage (%)**
Aluminum	90.9 – 94
Zinc	4.2 - 5.2
Magnesium	1.3 – 2
Copper	0.50 - 0.90

Tables 2: Aluminium 7129 (Al7129) Physical composition

Element	**Identification**
Chemical formula	TiC
Molar mass	59.89 g/mol
Appearance	black powder
Density	4.93 g/cm3
Melting point	3,160 °C (5,720 °F; 3,430 K)
Boiling point	4,820 °C (8,710 °F; 5,090 K)
Solubility in water	insoluble in water
Magnetic susceptibility (χ)	+8.0·10−6 cm3/mol

Tables 3: Titanum carbide properites

Property	**Value**
Density (g.cm-3)	2.52
Melting Point (°C)	2445
Hardness (Knoop 100 g) (kg.mm-2)	2900 - 3580
Fracture Toughness (MPa.m-½)	2.9 - 3.7
Young's Modulus (GPa)	450 - 470
Electrical Conductivity (at 25 °C) (S)	140

Tables 4: Boran carbide properites

APPLICATIONS:

Aluminium hybrid composites are a new generation of metal matrix composites that have the potentials of satisfying the demands of advanced engineering applications such as in used in the aircraft manufacturing sector, aerospace, automobile, space, underwater and transportation applications.

Talysurf measurements

Talysurf is a device used for measurement of surface roughness which known as Portable profilometer. which is based on the principle of a probe running across the surface to measure the variation of height as a function of distance.

3. EXPERIMENT PROCEDURE

First of all, the work-piece is mounted on the head stock of lathe. The other end of material is center-bored using center drill and then fixed with the tail stock respectively. Then, according to the design of experiment, different levels of parameters are set to get 9 numbers of run.

An initial roughness pass was performed on the work piece. Talysurf is then used to calculate the surface roughness (Ra) value for each run. In addition, tool wear at each cutting edge of the tool is calculated using a tool maker microscope. The Taguchi optimization technique was used to perform statistical analysis on the obtained data.

Fig2. Experimental set up for machining

Taguchi method is one of the powerful tools for optimization technique. This is based on the “Orthogonal Array” experiments which give much optimum setting of control parameters with reduced variance.

As a result, the Taguchi method produces the best results after optimization. The “Taguchi Orthogonal Array” produces a well-balanced (minimal) set of parameters. The signal-to-noise ratios, which are log functions of the desired output, serve as the objective function for the optimization method, which aids in data analysis and finding the best solution. The optimization problems involving the selection of the best level of parameters.

There are three signal-to-noise ratios of common interest for optimization of static problems.

I. Smaller-The-Better

$n = -10 \, Log_{10}$ [mean of sum of squares of measured data]

This is usually the chosen S/N ratio for all undesirable characteristics for which the ideal value is zero. But when the ideal value is zero, then the difference between measured data and ideal value is expected to be as small as possible.

The generic form of S/N ratio becomes: -

$n = -10 \, Log_{10}$ [mean of sum of squares of {measured - ideal}]

II. Larger-The-Better

$n = -10 \, Log_{10}$ [mean of sum squares of reciprocal of measured data]

taking the reciprocals of measured data and taking the value of S/N ratio as in smaller-the-better case, we can convert it to smaller-the-better case.

III. Nominal-The-Best

$n = 10 \, Log_{10}$ (square of mean/ variance)

This case arises when a specified value is most desired, meaning that neither a smaller nor a larger value is desirable.

4. EXPERIMENTAL OBSERVATION & ANALYSIS

L9 orthogonal array is used for the entire experimentation for turning operation according to Taguchi's orthogonal array theory. In the L9 orthogonal array, nine experimental runs are carried out, and the corresponding outputs are evaluated using the Taguchi optimization technique. The above-mentioned instruments are used to measure tool wears and surface roughness.

Sl. no.	Cutting speed	Feed	Depth of cut
1	1	1	1

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2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Table 5: Taguchi orthogonal array

Here, the process variables are cutting speed, feed and depth of cut. These are the input parameters for the Taguchi optimization. So, nine experiments are carried out as per this orthogonal array and corresponding output data are recorded serially. The surface roughness was measured on the surface of work piece.

Exp.No	Speed(Vc)	Feed(f)	DOC(d)	Ra	Tool Wear (micron)
1	180	25	0.2	2.34	0.8
2	180	80	0.6	4.2	1.05
3	180	125	1	10.2	1.0
4	350	25	0.6	2.24	1.12
5	350	80	1	3.31	0.8
6	350	125	0.2	5.42	0.7
7	500	25	1	2.13	0.6
8	500	80	0.2	2.68	1.3
9	500	125	0.6	4.85	1.38

Table 6: Observation table

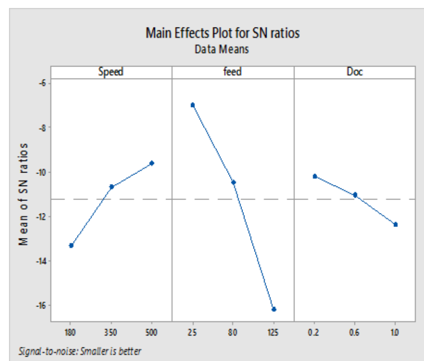
5. RESULTS & ANALYSIS

These above data are analysed by a power full statistical tool named Minitab software of latest version 18. First of all, the input parameters are defined in the software as per their corresponding value and then give the responses data to optimize. Here, the main objective of the problem is to minimize the value of tool wear and surface roughness. So, the criterion of Smaller-The-Better is adopted for the optimization.

5.1 Linear Model Analysis: S/N ratios versus Speed, Feed, Doc

Response Table for Signal to Noise Ratios
Smaller is better

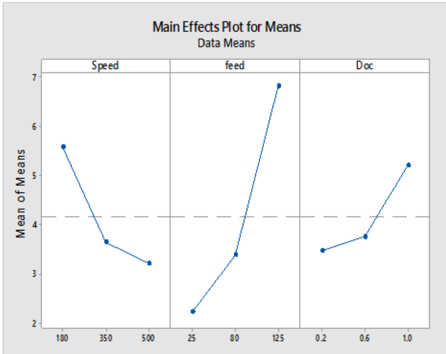
Level	Speed	feed	Doc
1	-13.340	-6.986	-10.209
2	-10.694	-10.475	-11.062
3	-9.615	-16.189	-12.379
Delta	3.725	9.203	2.170
Rank	2	1	3



5.2 Linear Model Analysis: Means versus Speed, Feed, Doc

Response Table for Means

Level	Speed	feed	Doc
1	5.580	2.237	3.480
2	3.657	3.397	3.763
3	3.220	6.823	5.213
Delta	2.360	4.587	1.733
Rank	2	1	3



Prediction Analysis

Exp .no	S/N Ratio	Mean
1.	-8.1022	2.99222
2.	-12.4439	4.43556
3.	-19.4752	9.31222
4.	-6.3082	1.35222
5.	-11.1144	3.96222
6.	-14.6589	5.65556
7.	-6.5465	2.36556
8.	-7.8659	1.79222
9.	-14.4327	5.50222

6. CONCLUSION

1. The experimentation with AMMC graded and a carbide cutting tool yielded a conclusion.

2. In order to minimise surface roughness and tool wear, a set of parameter levels is obtained.

3. Cutting velocity is found to be more important when calculating tool wear, and depth of cut is more important when experimenting with surface roughness.

4. A conformation test is performed in order to obtain the optimal setting; it is demonstrated that measuring tool wear is 0.659 micron and for surface roughness is 2.13 micron.

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